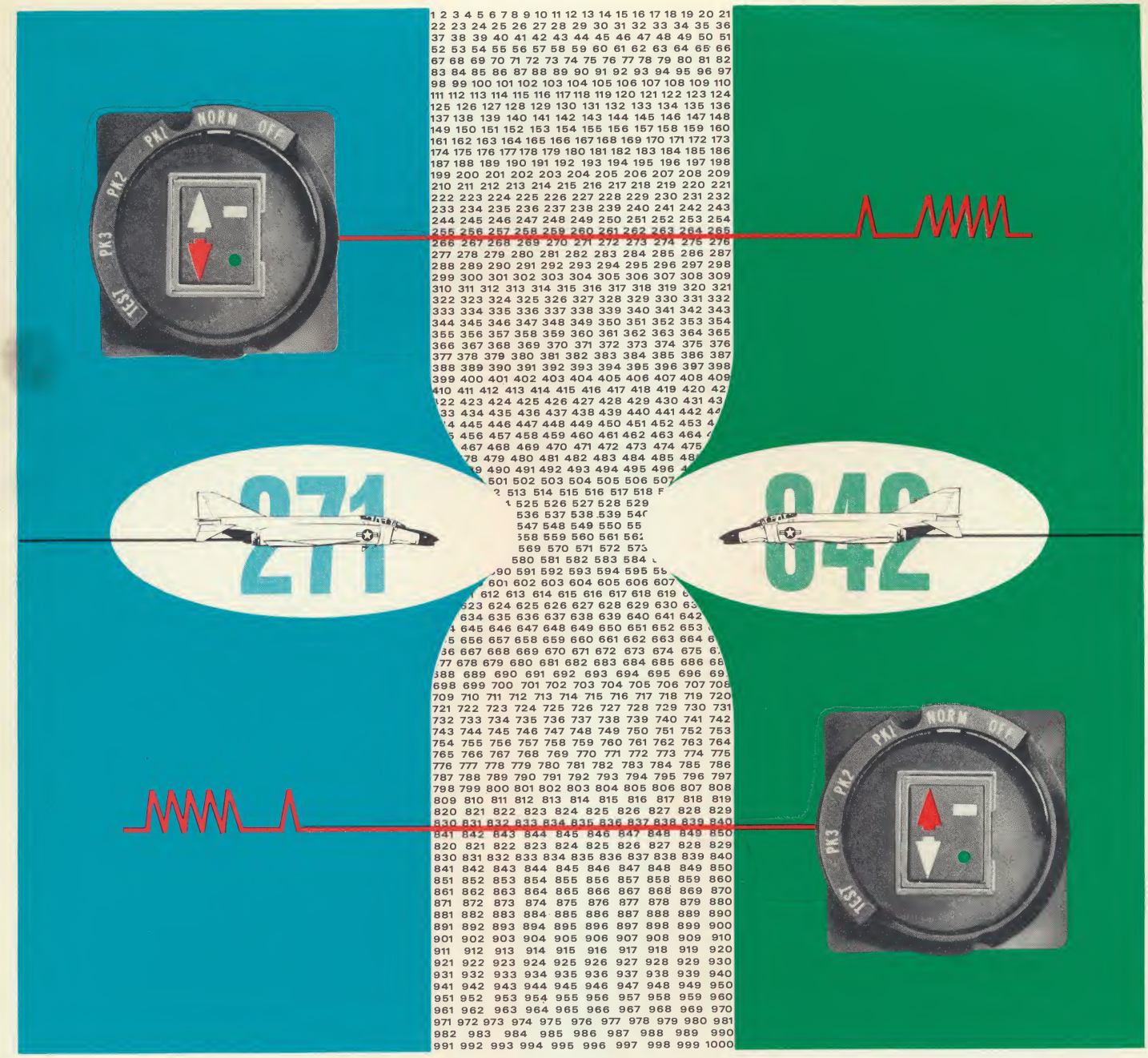


MCDONNELL

AIRBORNE COLLISION AVOIDANCE SYSTEM

AIRBORNE COLLISION AVOIDANCE SYSTEM *

*Patents Applied For

Utilizing a unique synchronization technique which creates a highly accurate time base for range and range-rate measurement, McDonnell engineers have developed a cooperative system for aircraft collision avoidance.

Airborne units function in cooperation with each other to provide warning and positive, unambiguous cockpit instructions for collision avoidance.

This system is being used on McDonnell jet fighter development and production flights which are flown in Special Operating Areas, segregated from other traffic by the FAA. Under these circumstances, the collision threat is generated by our own aircraft.

Uniform time, the heart of the system, is achieved by using clocks in each aircraft which are repeatedly synchronized by radio transmission to maintain an accuracy of a two tenths of a millionth of a second. The use of precise relative time permits reserving a definite time period (message slot) for each aircraft to transmit while all other aircraft listen. This method (time multi-plexing) prevents interference.

McDonnell engineers determined that many of the accepted criteria for collision warning, such as co-altitude and constant bearing, are ineffective when protection must be given from maneuvering aircraft. They found that *the single ever-present condition in all mid-air collisions is that the slant range decreases to zero*. The McDonnell system detects slant range by measuring the time delay between the start of another aircraft's message slot and the time at which the incoming signal is received.

An accurate stable oscillator frequency, a basic part of the airborne system, is multiplied to provide the UHF radio transmission frequency. Deviations from this frequency in an incoming signal are caused by Doppler frequency shift due to the relative velocity between the transmitting and receiving aircraft. This deviation is detected and converted into range rate. Thus, it is possible to get range (R) and the range rate ($\dot{R}$) from the same signal and to determine the time to closest approach by electronically dividing the range by the range rate ($R/\dot{R}$).

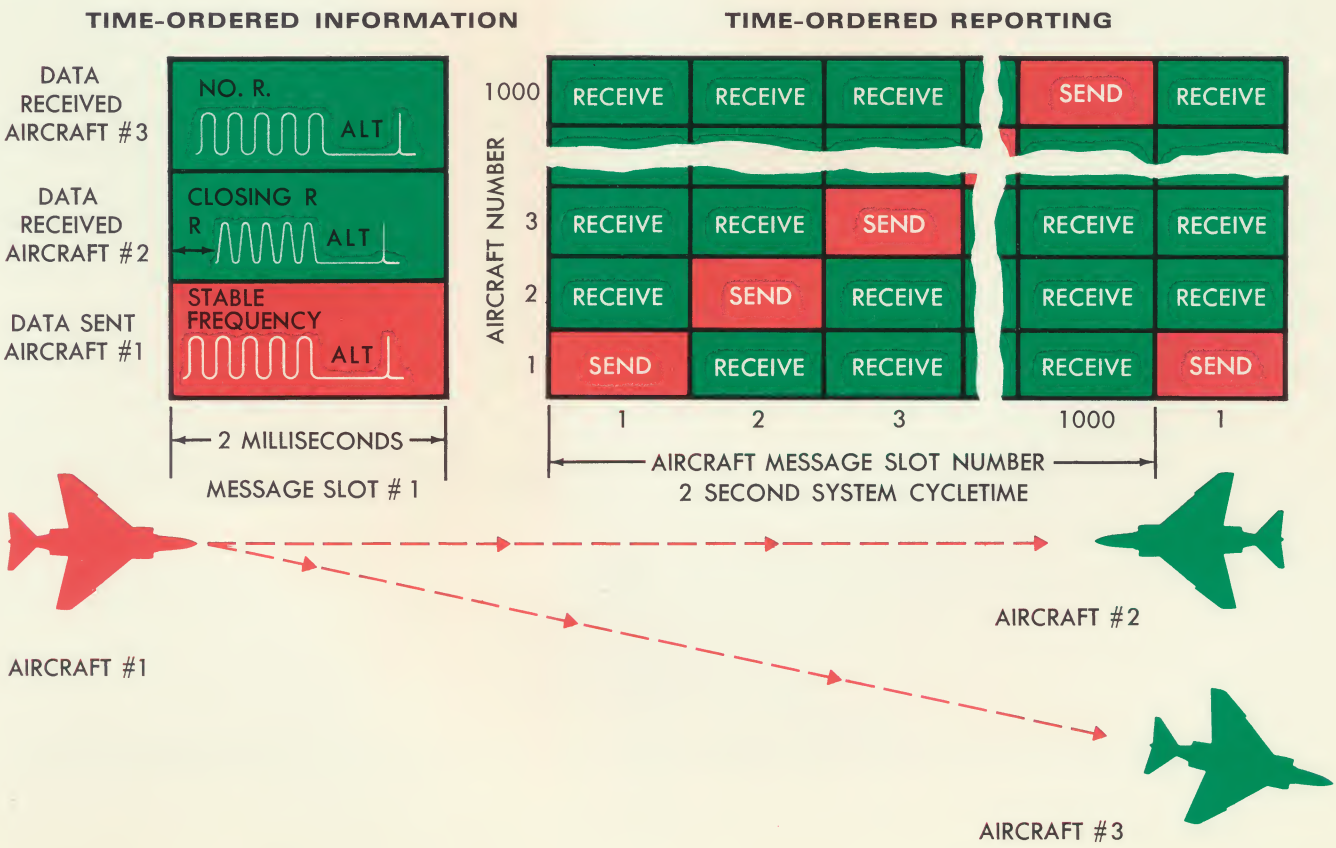
Since collisions could occur between aircraft approaching each other below the limits of Doppler detection, the system warns of aircraft flying at co-altitude and within 1½ miles, regardless of range rate.

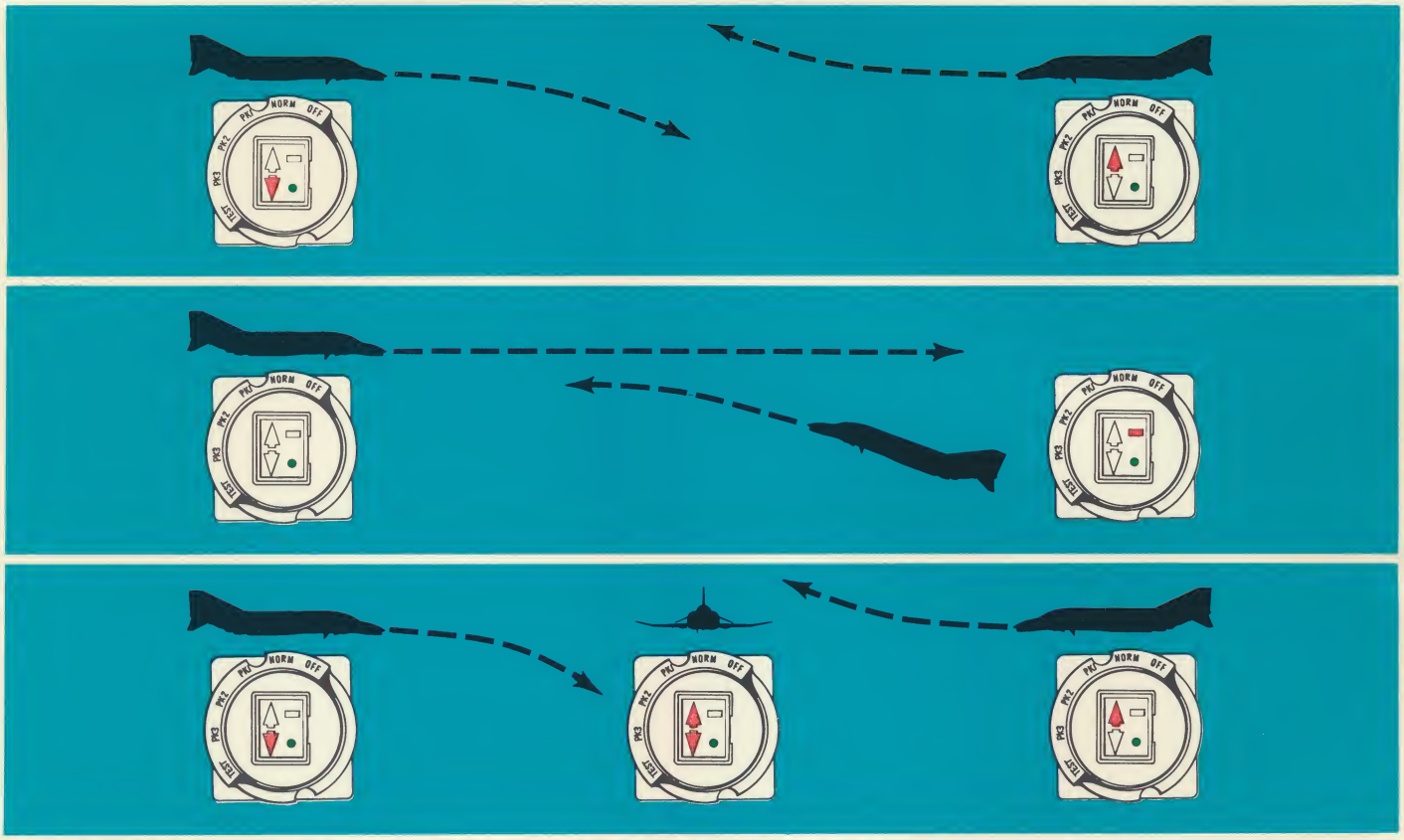
Altitude screening is used to eliminate targets which are not a threat by reason of widely differing altitudes. For altitude screening, the rate of climb or descent (as well as the present altitude) is considered. Barometric altitude is coded in the transmitted signal. The receiving aircraft checks this altitude information against its present altitude and any

The airborne system has been packaged in a pod which fits into the missile well on the Phantom facilitating interchangeability of units for high utilization.

altitudes it will pass through in 60 seconds if it is in a climb or dive.

Screening on the basis of range, range rate, and altitude puts a minimum threat envelope around each aircraft and eliminates false alarms in the system. All incoming signals are continuously examined to determine which are threats in terms of time or range. No aircraft is considered a threat until it is either 60 seconds or 1½ miles away and at the same





altitude, or occupying an altitude that the receiving aircraft will pass through within the next 60 seconds.

McDonnell uses the message slot number of each aircraft to establish a non-ambiguous climb-dive escape maneuver. An aural signal tells the pilot to look at the indicator. The pilot of the aircraft with the lower message slot is told to "descend", and in the aircraft with the higher message slot the pilot sees an upward pointing arrow indicating "climb". In the unlikely instance more than two aircraft are involved in a simultaneous collision situation, the highest and lowest message slot airplanes are given the "climb" and "descend" instructions, and the aircraft in the intermediate message slot or slots is given both an up and down signal until one or the other aircraft clears his altitude and he becomes the highest or the lowest message slot involved and is then given appropriate instructions.

In a climbing or diving aircraft, the present altitude and the anticipated altitudes for the next 60 seconds are screened for collision threats. If a climbing or diving airplane receives a warning of an impending collision, a level-off signal is given. The aircraft which is flying level in this situation is not warned. Responsibility for avoiding the collision rests with the pilot of the climbing or diving airplane.

The number of aircraft accommodated by the system is established by the signal repetition rate and the detection distance necessary to provide enough warning time to avoid a collision. A system combining a 150-mile range with transmissions once every two seconds can accommodate 1,000 message slots (1,000 aircraft) and provide a 60-second warning for aircraft closing at speeds up to Mach 4.

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